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Response to Office Action Dated 08/02/2004

1 Claims 1—23: Cancelled.

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3 24. (Currently amended.) A method for determining shadowing cast  
4 onto a bump mapped surface by one or more bumps thereon, where the bump  
5 mapped surface is represented by a plurality of polygons each having a plurality of  
6 vertices, each vertex defining a point in a tangent plane of the bump mapped  
7 surface, where a normal vector at each said vertex is perturbed to define a bump  
8 map of the bump mapped surface that includes a plurality of bumps on the surface,  
9 the method comprising:

10 defining a horizon map of the surface including, for each of a plurality of  
11 radial directions in the tangent plane around each said vertex, the largest angle  
12 between the normal vector and any direct ray of light to the vertex; and

13 storing the horizon map as a set of texture maps corresponding to the  
14 surface on the three-dimensional graphical ~~object~~; object; and

15 wherein for each said vertex, each said texture map has a plurality of color  
16 channels, each said color channel having encoded therein the largest angle  
17 between the normal vector and any direct ray of light to the vertex that does not  
18 contact any of the bumps on the surface.  
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1 25. (Original.) The method as defined in Claim 24, further comprising:  
2 executing an interactive program that defines a light source by a  
3 direction relative to:  
4 the tangent plane of the surface; and  
5 the normal of each said vertex;  
6 determining at least two of the radial directions stored in the horizon  
7 map with respect to the direction of the light source;  
8 interpolating from the largest angles at the at least two radial  
9 directions of the horizon map to obtain the portion of each said polygon  
10 that is in the light from the light source;  
11 rendering the surface on the three-dimensional graphical  
12 object, from a given point of view, to include only the portion of each said  
13 polygon that is in the light from the light source;  
14 interactively receiving instructions to change the direction of  
15 the light source relative to the surface on the three-dimensional graphical  
16 object;  
17 repeating the determining by interpolation step using the changed  
18 direction of the light source relative to the surface on the three-dimensional  
19 graphical object; and  
20 repeating the rendering.  
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1       26.   (Cancelled.)

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3       27.   (Currently amended.) The method as defined in Claim ~~[[26]]~~24,  
4 wherein:

5       the set of texture maps comprises two texture maps; and

6       each said texture map:

7           ~~corresponding~~ corresponds to not more than four of the radial  
8 directions; and

9           has four ~~color~~ color channels each having not more than one radial  
10 direction encoding for the corresponding largest angle for each vertex  
11 between the normal vector and any direct ray of light to the vertex that does  
12 not contact any of the bumps on the surface.

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14       28.   (Cancelled.)  
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1           29. (Original.) A method for rendering a frame in a frame buffer  
2 represented by a plurality of pixels, the frame depicting a three dimensional  
3 graphical object that is defined by surfaces each having a surface geometry  
4 defined by a parameterization of a plurality of polygons, each polygon being  
5 defined by vertices, each vertex  $(u,v)$  having a bump map scalar value  $F(u,v)$   
6 defining a bump, each vertex  $(u,v)$  having a perturbed normal map vector value  
7  $N'(u,v)$  from the bump map scalar value  $F(u,v)$ , each vertex  $(u,v)$  having  $M$  basis  
8 maps  $(B_k=1 \dots M(s, t))$ , each vertex  $(u,v)$  having  $M$  horizon maps for each of  $M$   
9 radial directions  $(\theta_k=1 \dots M)$  in the tangent plane of the vertex  $(u, v)$ , wherein each  
10 of the  $M$  horizon maps includes the largest angle  $\phi(u,v,\theta_k=1 \dots M)$  between the  
11 perturbed normal map vector value  $N'(u, v)$  and any direct ray to the vertex  $(u, v)$ ,  
12 the method comprising:

13           (i) defining a light vector  $(L)$  having a direction defined by:

14                       the angle  $\theta_L$  between the light vector  $(L)$  and the plane  
15                       formed by coordinates  $(u,v)$ ; and

16                       the angle  $\phi_L$  between the light vector  $(L)$  and the perturbed  
17                       normal map vector value  $N'(u,v)$ ;

18           (ii) inverting a local tangent frame by  $[P_u, P_v, N]^T = [S^T, T^T, N^T]$  to  
19           obtain an inverted tangent frame  $(S,T)$ ;

20           (iii) taking the dot product of the light vector  $(L)$ :

21                       with the first two components of the inverted frame  
22                        $(S,T)$  to obtain the projection of the light vector  $(L)$  into the  
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1 coordinate space in the tangent plane at a coordinate pair (s,t);  
2 and

3 with the perturbed normal map vector value  $N'(u, v)$  at  
4 the vertex to obtain cosine ( $\phi_L$ );

5 (iv) setting the camera angle of the rendering to a point of view to be  
6 rendered for the frame to write into the space of a texture map;

7 (v) computing first and second texture effects on each pixel in the frame  
8 buffer, respectively, from first and second sets of the M directions stored as  
9 texture maps, wherein each said largest angle  $\phi(u, v, \theta_k)$  is in one of a  
10 plurality of color channels of a texture map, wherein one of the M  
11 directions corresponds to each said color channel of the texture map, and  
12 wherein the first and second texture effects are defined, respectively by:

13 a basis map  $B_1(s, t)$  of said M basis maps ( $B_{k=1...M}(s, t)$ ), and  
14 a horizon map,  $\phi_1(u, v)$  of said M horizon maps; and

15 a basis map  $B_2(s, t)$  of said M basis maps ( $B_{k=1...M}(s, t)$ ), and  
16 a horizon map,  $\phi_2(u, v)$  of said M horizon maps;

17 (vi) storing the first and second texture effects for each pixel in  
18 the frame buffer in a texture map  $\phi(\theta_{\text{LIGHT}})$ ;

19 (vii) for a given camera perspective view:

20 on a first operation, rendering a model of the three  
21 dimensional graphical object with an ambient low level  
22 lighting term only;

23 on a second operation:  
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1                    setting an alpha test and a stencil function to  
2                    accept only those pixels in the frame buffer that have a  
3                    non-zero alpha test result;

4                    setting a color mask upon the frame buffer,  
5                    wherein the color mask will not write to the color  
6                    channels of the texture maps, whereby the ambient low  
7                    level lighting term previously rendered is preserved;

8                    drawing, using multi-texturing, for the angle  
9                    ( $\phi_L$ ) and the angle to the horizon ( $\theta_L$ ), the first and  
10                   second texture effects on each pixel in the frame  
11                   buffer, which are, respectively,  $\cos(\phi_L)$  that is  
12                   greater than  $\phi_L$ , and  $\phi(\theta_{\text{LIGHT}})$ ;

13                   on a third operation:

14                         setting the alpha test off;

15                         setting the color mask upon the frame  
16                         buffer to allow writing to the color channels of  
17                         the texture maps;

18                         setting the stencil function to only draw  
19                         pixels in the frame buffer that have a non-zero  
20                         alpha test result;

21                         setting a blending function to accumulate  
22                         into the frame buffer with the ambient low level  
23                         lighting term;

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1 drawing the vector valued perturbed  
2 normal map  $N'(u,v)$ ; and

3 displaying the three dimensional  
4 graphical object defined by pixels in the frame  
5 buffer, wherein the displayed object has an  
6 ambient only term in shadowed regions and  
7 normal bump mapping in non-shadowed  
8 regions.

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10 30. (Original.) The method as defined in Claim 29, further comprising:  
11 interactively receiving instructions that change the definition of the  
12 light vector (L) with respect to each vertex (u,v); and  
13 repeating (i) through (vii) using the changed definition of the light  
14 vector (L).

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16 Claims 31—41: Cancelled.  
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1           42. (New.) One or more computer-readable media comprising computer-  
2 executable instructions for determining shadowing cast onto a bump mapped  
3 surface by one or more bumps thereon, where the bump mapped surface is  
4 represented by a plurality of polygons each having a plurality of vertices, each  
5 vertex defining a point in a tangent plane of the bump mapped surface, where a  
6 normal vector at each said vertex is perturbed to define a bump map of the bump  
7 mapped surface that includes a plurality of bumps on the surface, the computer-  
8 executable instructions comprising instructions for:

9           defining a horizon map of the surface including, for each of a plurality of  
10 radial directions in the tangent plane around each said vertex, the largest angle  
11 between the normal vector and any direct ray of light to the vertex;

12           storing the horizon map as a set of texture maps corresponding to the  
13 surface on the three-dimensional graphical object; and

14           wherein for each said vertex, each said texture map has a plurality of color  
15 channels, each said color channel having encoded therein the largest angle  
16 between the normal vector and any direct ray of light to the vertex that does not  
17 contact any of the bumps on the surface.



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1 43. (New.) The one or more media as recited in claim 42, comprising  
2 further instructions for:

3 executing an interactive program that defines a light source by a  
4 direction relative to:

5 the tangent plane of the surface; and

6 the normal of each said vertex;

7 determining at least two of the radial directions stored in the horizon  
8 map with respect to the direction of the light source;

9 interpolating from the largest angles at the at least two radial  
10 directions of the horizon map to obtain the portion of each said polygon  
11 that is in the light from the light source;

12 rendering the surface on the three-dimensional graphical  
13 object, from a given point of view, to include only the portion of each said  
14 polygon that is in the light from the light source;

15 interactively receiving instructions to change the direction of  
16 the light source relative to the surface on the three-dimensional graphical  
17 object;

18 repeating the determining by interpolation step using the changed  
19 direction of the light source relative to the surface on the three-dimensional  
20 graphical object; and

21 repeating the rendering.  
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1 44. (New.) The one or more media as recited in claim 42, wherein:

2 the set of texture maps comprises two texture maps; and

3 each said texture map:

4 corresponds to not more than four of the radial directions; and

5 has four color channels each having not more than one radial  
6 direction encoding for the corresponding largest angle for each vertex between the  
7 normal vector and any direct ray of light to the vertex that does not contact any of  
8 the bumps on the surface.

9  
10 45. (New.) One or more computer-readable media comprising computer-  
11 executable instructions for rendering a frame in a frame buffer represented by a  
12 plurality of pixels, the frame depicting a three dimensional graphical object that is  
13 defined by surfaces each having a surface geometry defined by a parameterization  
14 of a plurality of polygons, each polygon being defined by vertices, each vertex  
15  $(u,v)$  having a bump map scalar value  $F(u,v)$  defining a bump, each vertex  $(u,v)$   
16 having a perturbed normal map vector value  $N'(u,v)$  from the bump map scalar  
17 value  $F(u,v)$ , each vertex  $(u,v)$  having  $M$  basis maps  $(B_k=1 \dots M(s, t))$ , each vertex  
18  $(u,v)$  having  $M$  horizon maps for each of  $M$  radial directions  $(\theta_k=1 \dots M)$  in the  
19 tangent plane of the vertex  $(u, v)$ , wherein each of the  $M$  horizon maps includes  
20 the largest angle  $\phi(u,v,\theta_k=1 \dots M)$  between the perturbed normal map vector value  
21  $N'(u, v)$  and any direct ray to the vertex  $(u, v)$ , the computer-executable  
22 instructions comprising instructions for:

23 (i) defining a light vector  $(L)$  having a direction defined by:

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1 the angle  $\theta_L$  between the light vector (L) and the plane  
2 formed by coordinates (u,v); and

3 the angle  $\phi_L$  between the light vector (L) and the perturbed  
4 normal map vector value  $N'(u,v)$ ;

5 (ii) inverting a local tangent frame by  $[P_u, P_v, N]^T = [S^T, T^T, N^T]$  to  
6 obtain an inverted tangent frame (S,T);

7 (iii) taking the dot product of the light vector (L):

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9 with the first two components of the inverted frame  
10 (S,T) to obtain the projection of the light vector (L) into the  
11 coordinate space in the tangent plane at a coordinate pair (s,t);  
12 and

13 with the perturbed normal map vector value  $N'(u, v)$  at  
14 the vertex to obtain cosine ( $\phi_L$ );

15 (iv) setting the camera angle of the rendering to a point of view to be  
16 rendered for the frame to write into the space of a texture map;

17 (v) computing first and second texture effects on each pixel in the frame  
18 buffer, respectively, from first and second sets of the M directions stored as  
19 texture maps, wherein each said largest angle  $\phi(u,v,\theta_k)$  is in one of a  
20 plurality of color channels of a texture map, wherein one of the M  
21 directions corresponds to each said color channel of the texture map, and  
22 wherein the first and second texture effects are defined, respectively by:

23 a basis map  $B_1(s, t)$  of said M basis maps ( $B_{k=1 \dots M}(s, t)$ ), and  
24 a horizon map,  $\phi_1(u, v)$  of said M horizon maps; and  
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1 a basis map  $B_2(s, t)$  of said M basis maps ( $B_{k=1...M}(s, t)$ ), and  
2 a horizon map,  $\phi_2(u, v)$  of said M horizon maps;

3 (vi) storing the first and second texture effects for each pixel in  
4 the frame buffer in a texture map  $\phi(\theta_{\text{LIGHT}})$ ;

5 (vii) for a given camera perspective view:

6 on a first operation, rendering a model of the three  
7 dimensional graphical object with an ambient low level  
8 lighting term only;

9 on a second operation:

10 setting an alpha test and a stencil function to  
11 accept only those pixels in the frame buffer that have a  
12 non-zero alpha test result;

13 setting a color mask upon the frame buffer,  
14 wherein the color mask will not write to the color  
15 channels of the texture maps, whereby the ambient low  
16 level lighting term previously rendered is preserved;

17 drawing, using multi-texturing, for the angle  
18  $(\phi_L)$  and the angle to the horizon  $(\theta_L)$ , the first and  
19 second texture effects on each pixel in the frame  
20 buffer, which are, respectively,  $\cosine(\phi_L)$  that is  
21 greater than  $\phi_L$ , and  $\phi(\theta_{\text{LIGHT}})$ ;

22 on a third operation:

23 setting the alpha test off;

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1                    setting the color mask upon the frame  
2                    buffer to allow writing to the color channels of  
3                    the texture maps;

4                    setting the stencil function to only draw  
5                    pixels in the frame buffer that have a non-zero  
6                    alpha test result;

7                    setting a blending function to accumulate  
8                    into the frame buffer with the ambient low level  
9                    lighting term;

10                   drawing the vector valued perturbed  
11                   normal map  $N'(u,v)$ ; and

12                   displaying the three dimensional  
13                   graphical object defined by pixels in the frame  
14                   buffer, wherein the displayed object has an  
15                   ambient only term in shadowed regions and  
16                   normal bump mapping in non-shadowed  
17                   regions.

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19                   46. (New.) The one or more media as recited in claim 45, comprising  
20                   further instructions for:

21                   interactively receiving instructions that change the definition of the  
22                   light vector (L) with respect to each vertex (u,v); and

23                   repeating (i) through (vii) using the changed definition of the light  
24                   vector (L).  
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